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A Study on the Airborne Particulates Matter in Selected Museums of Peninsular Malaysia

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Abstract

An indoor pollutant gives harmful effects to human health and became one of the main causes of the cultural heritage deterioration. The research is focuses on the airborne particulates at the indoor of the museum galleries. Equipment used to sample inhalable dust was the 7-hole sampler and the Cyclone sampler for sample respirable dust. The results show that mass concentrations at selected location were exceeding the limit of safety Indoor Air Quality (IAQ) and Malaysia standard limit for TSP and PM10 in 8 hours sampling. Thus, it is important to control the level of contaminants within the buildings for safety purposes.

Keywords : Air pollution; airborne particulates; indoor; human health; cultural heritage

1. Introduction

The problem of Indoor Air Quality (IAQ) has given crucial impact to human health and been discussed by the world for about half century. Pollutants in the air are caused by natural events and human activities. In 1991, vehicle emissions contributed 75 percent of the total emissions into the air, and increased by 12 percent over 1987. Kuala Lumpur is one of the 15 Asian cities that have the greatest

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levels of pollution. The average reported, the suspended levels at 53 percent of monitoring stations far exceeded WHO standards (Acson, 2010).This research focuses on the human activities that contributes to air pollution such as industrial activity, construction works and driving vehicles. The scope of area for this research is airborne particulates, human health and cultural heritages. The relationship of these erratic matters will be discussed by studying on the effects of airborne particulates towards heritage items at the selected study sites in Manjung District, which is near to the industrial activity; Manjung Coal-Fired Power Plant and Lumut Power Plant, Perak Darul Ridzuan and also at National Museum, Kuala Lumpur, Malaysia.

It is to be highlighted here that this research aims is to focus on the mass concentration of airborne particulates matter indoor of heritage building at Manjung District, Perak Darul Ridzuan and National Museum, Kuala Lumpur. The aim will be attained by determining the type of airborne particulates in heritage buildings, identifying the type of damage to historical materials because of dust, pollen, and particles as a part of airborne particulates, reducing the harmful effect towards human health, and finally suggesting and recommending solutions to overcome the issues of airborne particulates. The objectives of the research acknowledged as follows :-

- To identify the sources of airborne particulates in selected museums
- To measure and quantify particulate matters and IAQ in the selected museum galleries
- To classify the effects of relative humidity and temperature towards artefacts
- To study the effects of airborne particulates towards human health and cultural heritage
- The propose the methods of displaying artefacts and reducing particulates matter in museum

1.1. Atmospheric pollution

Atmospheric pollution is the presence of one or more contaminants in the air in such a concentration and of such duration as to cause a nuisance or to be injurious to human life, animal life or vegetation (Zactruba, 2009). Global climate change refers to changes in the climate of the earth as a whole, caused by human activities releasing an overabundance of greenhouse gases into the atmosphere. The pollutants of the air may come from various sources such as industrial activity like factory emissions, waste products, transportation and construction works (B.C.Air Quality, 2009). According to Acson International in their Healthy Air Booklet (Acson, 2010), the main sources of air pollution in Malaysia are motor vehicles, power stations, industrial fuel burning and processes, domestic fuel burning, burning of municipal and industrial waste.

Recent studies in built environment and science prove that Malaysia is in a high risk on the effects of air pollution caused by industrial activity (manufacturing processes, oil refineries, etc.), construction works (building construction), transportations (driving vehicles), power plants stations (coal-fired power plant or fossil fuels), open burnings, and also by natural disasters such as windstorms, earthquakes, and so on (SAM, 2010). The large number of health-damaging air pollutants include Carbon Monoxide (CO), Nitrogen Dioxide (NO_2), Ozone (O_3), Sulphur Dioxide (SO_2), and Particulates matter specifically coarse, fine and inhalable PM_{10} and $PM_{2.5}$ (Nik Nurul Hidayah and Shamzani Affendy, 2011).

Air pollution is caused by gases and particles, both liquid and solid, which contaminate the environment. As highlighted in the article by Pupatunda (2010), scientists link this kind of contamination of the air to adverse health effects such as respiratory diseases and even cancer. Sjaak Slanina (2008) has stated that most of pollutants are emitted both by natural as well as by anthropogenic sources. Natural sources are not influenced by humans or by human-induced activities. Those activities will generate airborne particulates and hazardous gases that can pollute the air that we inhale. Atmospheric pollution, by definition, causes harm to the comfort, health or welfare of people or the environment. One index of

atmospheric pollution that is relevant to people's health is the PM_{10} score which measures the number of particles smaller than 10 microns per cubic meter of air (Zactruba, 2009).

1.2. Airborne particulates matter

Particulate Matter (PM) is a complex mixture of extremely small solids and liquid droplets. It is made up of a number of components, including acids (such as nitrates and sulfates), organic chemicals, metals, and soil or dust particles as stated by the CAI-Asia Center (2010). Airborne particulate matter represents a complex mixture of organic and inorganic substances. Mass and composition in urban environments tend to be divided into two principal groups: coarse particles and fine particles. The barrier between these two fractions of particles usually lies between 1 μm and 2.5 μm. However, the limit between coarse and fine particles is sometimes fixed by convention at 2.5 μm in aerodynamic diameter ($PM_{2.5}$) for measurement purposes.The smaller particles contain the secondarily formed aerosols (gas-to-particle conversion), combustion particles and recondensed organic and metal vapors. The larger particles usually contain earth crust materials and fugitive dust from roads and industries (Green Facts Scientific Board, 2010).

All current air quality standards for particles within and outside Asia refer to the weight of particles measured in units of $\mu g/m^3$. In Malaysia, the air quality is measured using an indicator that is known as Air Pollution Index (API). Usually, the particulates matter or ozone is the air pollutant that determines the API reading. The standard of Total Suspended Particulate (TSP) for 24 hours in Malaysia by Department of Environment, DOE (2006) is 260 $\mu g/m^3$ or 0.260 mg/m^3. Thus, the standard TSP in 8 hours is about 0.08 mg/m^3. Furthermore, standard guideline for PM_{10} in Malaysia is 0.05mg/m^3 in 8 hours sampling. This standard level of airborne particulates in Malaysia will be used as a guideline in analyzing data gained after dust sampling process conducted by the researcher at selected site studies. The annual average value of particulate matter concentration is shown in Table 1.

Table 1. Malaysia Ambient Air Quality Standard Guidelines; Source: DOE, (2006)

Pollutant	Averaging Time	Malaysia Guidelines	
		Ppm	($\mu m/m^3$)
Ozone (O_3)	1 hour	0.10	200
	8 hour	0.06	120
Carbone Monoxide (CO)	1 hour	30.0	35
	8 hour	9.0	10
Nitrogen Dioxide (NO_2)	1 hour	0.17	320
	24 hour	0.04	10
Sulphur dioxide (SO_2)	1 hour	0.13	350
	24 hour	0.14	105
Particulate Matter (PM_{10})	24 hour		150
	12 month		50
Total Suspended Particulate (TSP)	24 hour		260
	12 month		90
Lead (Pb)	3 month		1.5

2. Materials and methods

2.1. Literature review

The literature review outcomes established from primary and secondary data collection includes review papers from academic journals, conference papers and related previous dissertation. The main purpose of doing literature review is to collect information and data from the right sources in order to obtain all the theories related to research from various sources and to study the different techniques and methods used by the professionals. Some internet articles are also being utilised in order to complement the understanding of literature part. For this research, the data collected are focusing on air pollutions, airborne particulates and its hazardous effect towards human health and cultural heritage objects.

2.2. Selection of case study

A. National Museum was officially opened by His Majesty, the Third Yang di-Pertuan Agong, Tuanku Syed Putra Al-Haj Ibni Al-Marhum Syed Hassan Jamalullail on 31st August 1963. Located in the heart of the city of Kuala Lumpur, the National Museum (Muzium Negara) built in the style of a Malay palace is the guardian of the nation's history (NMO, 2011). This historical building is surrounded by six to seven building constructions in the previous couple of year. It is the best case study for this research as construction activities did give big impact to the air pollution issues in Malaysia. From the three case studies, mass concentrations of airborne particulates calculated and compared in order to determine which building has the highest level of pollutants indoor by the possible sources of pollution at the location selected.

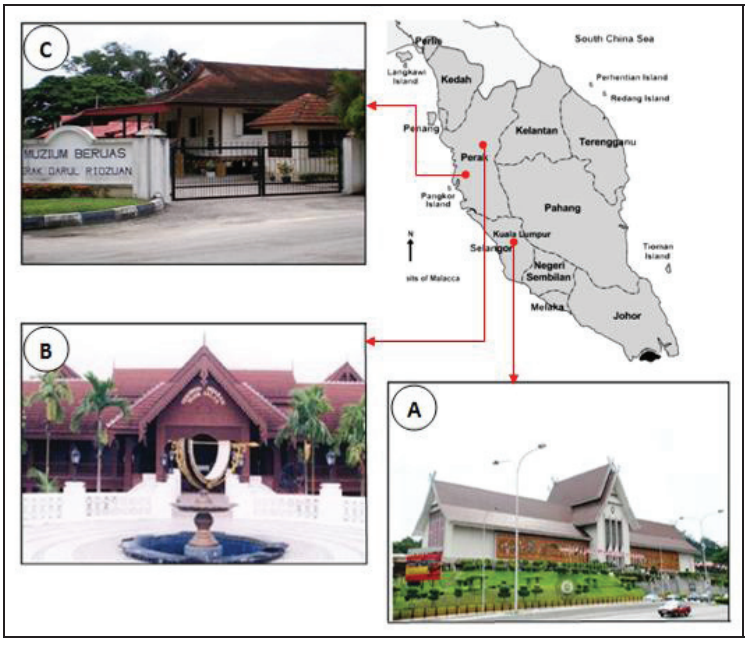

Fig. 1. Selected museums in Peninsular Malasyia as the location for airborne particulates sampling ; National Museum (A), Pasir Salak Historical Complex (B), and Beruas Museum (C).

B. The Pasir Salak Historical Complex is exactly what its names implies; a memorial to the remarkable history of Pasir Salak and the people of Perak. It is situated at 70 km from the Ipoh city (Art Melayu, 2009). This historical complex was chosen as one of the case studies because its location that is besides the river. The particulates, dust or sand that are blown by the river wind may affect the air quality indoor of the complex. Besides, it is to investigate whether the particulates from the combustion of coals at Manjung Coal-Fired Power Plant station reach that site.

C. Beruas Archaeological Museum is a small museum in the town of Beruas, in Manjung District, Perak. The museum is devoted to showcasing artefacts from the obscure Hindu kingdom of Gangga Negara that flourished in the Manjung district from the 2nd century to the 11th century AD. The museum is housed in a former courthouse and opened to the public in July, 1995 (Tourism Forum, 2010). This museum is located near to the road which was used as the main road at the place. The traffic flows at site were quite busy everyday. The capability of the airborne particulates that come from transportations is high. Air sampling was done inside the exhibition gallery.

2.3. Environmental air sampling

The scientific data collections are expanded further by measuring the content of airborne particulates ; minutes particles that are suspended in the air, done along with sampling process. The tools and equipments used includes Mass Balance, 7-Hole sampler, Cyclone sampler, Desiccator, Pumps, Calibrators, and other tools to support the usage of those equipments. Sampling devices are use to collect the airborne particulate from a measured volume of air which are measured as mass concentration and reported as milligram of particulate per cubic meter of air (mg/m^3). Inhalable 8-hours air sampling are using Casella 7-hole sampler at 2.0 L/min air flow (Fig.2a) and cyclone sampler at 2.2 L/min air flow for respirable 8-hours air sampling (Fig.2b).

Fig. 2. (a) 7-hole sampler ; (b) Cyclone sampler

2.4. Data collection

Data collections are divided into two types which could be gained from primary sources and secondary sources. Primary data is the data that we can get by the first hand, the methods and collections of data that are assessed and gained at selected site studies or in situ such as airborne particulates sampling. Secondary data is the data that are readily available, it includes literature review such as existing journals, paperwork, articles, newspaper, books, reports or any other data that are already exist. Besides gaining data from other resources, researcher had quantified the particulates with the chosen method in order to get more constructive data. Data was collected inside the exhibition galleries of selected museums. The information about the day, date and time when the data was collected are as stated in Table 2.

Table 2. The information of data gained at selected museum in Peninsular Malaysia

Location	Data collection		Time /period		
	Day	Date	a.m	p.m	duration
National Museum	weekday	15/03/2011	9.00	5.00	8 hour
Beruas Museum	weekday	21/03/2011	8.30	4.30	8 hour
Pasir Salak Historical Complex	weekday	22/03/2011	9.45	5.45	8 hour

The mass concentration of the airborne particulates suspended in the air was calculated and compared base on the environmental condition of the site study and the possible sources of the particulates at those locations. In addition to relate the research with cultural heritage, Testo 461 (Fig.3) was used to read temperature and relative humidity indoor of the selected case study. It is to prove that changes in temperature and humidity also give bad impact towards cultural heritage objects or artefacts inside the building studied.

Fig. 3. Testo 461

3. Results and discussion

The issues of Indoor Air Quality (IAQ) in Malaysia buildings discussed in such studies by Roslina (2010) and Norsyamimi (2011). They agreed with the statement by ShamzaniAffendy (2007) that the percentage of the respirable dust towards total inhalable dust collected outdoor is more than the percentage of the respirable dust towards total inhalable dust collected indoor. Nevertheless, the mass concentration of airborne particulates in their case studies at Perak Darul Ridzuan and Kuala Lumpur are

exceeding the standard level of Total Suspended Particulates (TSP) in Malaysia (EPD, 1987) and over the limit of good IAQ stated by CAI-Asia Center (2010). Sampling of airborne particulates Indoor and Outdoor have been done at three (3) selected site or case studies which are National Museum at Kuala Lumpur, Pasir Salak Historical Complex, and Beruas Museum that are located in Manjung District at Perak Darul Ridzuan, Malaysia.

3.1. Particulates matter in exhibition gallery

According to the National Standard level of Total Suspended Particulates (TSP) in Malaysia as stated by CIA-Asia Center (2010), the standard level of TSP in Malaysia is 0.260 mg/m^3 which means 0.260 mg/m^3 in 24 hours. Based on this, it can be highlighted that the standard level of TSP for Malaysia in 8 Hours period is 0.08 mg/m^3 while PM_{10} is 0.05 mg/m^3. The researcher agrees that the mass concentration gathered from 7-Hole sampler should be higher than the Cyclone sampler as stated by Shamzani (2007), that the Cyclone Respirable Dust Sampler produced airborne mass concentration which results in excess of other instruments, which linked to high shear forces generated within the instruments, breaking up particles aggregates and increasing the mass of respirable dust.

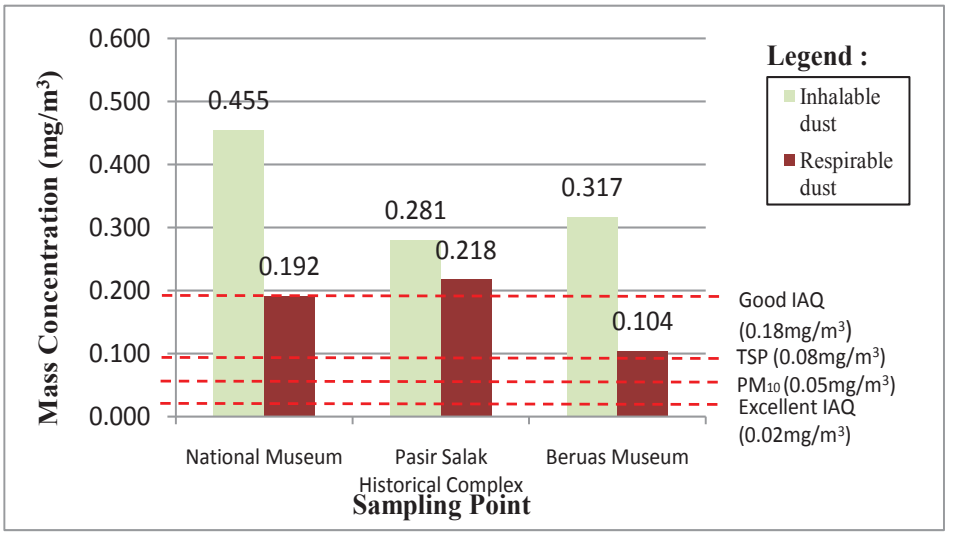

Fig. 4.Comparison of Airborne Particulates mass concentration in selected museums with the level of PM_{10} (DOE,2006), Good and Excellent IAQ by EPD (1987) in 8 Hours

From the findings gathered, it can be noted that the level of respirable and inhalable dust at National Museum and Pasirsalak Historical Complex are higher than the standard level based on the Hong Kong Air Quality Objectives under Air Pollution Control Ordinance by EPD (1987), that a good IAQ of indoor for respirable dust is 0.018 mg/m^3 in average 8 hours and 0.02 mg/m^3 for excellent IAQ. As the mass concentration for respirable particulate is over the standard level of Good IAQ and the standard level of Total Suspended Particulates (TSP) and PM_{10} for Malaysia, the situation may create high risk of exposure towards airborne particulates within the building on the occupants which need to be overcome and

controlled. The particulates that are trapped in the museum buildings may become a risk and create health problems to the visitors as well.

3.2. Temperature and relative humidity collection

Table 3 is the summary of relative humidity and temperature Indoor by case studies which are recorded at National Museum, Beruas Museum, and Pasir Salak Historical Complex, Perak. The relative humidity and temperature at those locations were noted down by the researcher in the morning and evening to make comparison and identify the changes of the readings whether increasing or decreasing.

Table 3. Average Relative Humidity and Temperature Indoor of the selected museum galleries

Location	Relative Humidity (%)			Temperature (˚C)		
	a.m	p.m	change	a.m	p.m	change
National Museum	65.1	54.4	10.7	26.5	28.7	2.2
Beruas Museum	56.9	50.0	6.9	23.7	24.5	0.8
Pasir Salak Historical Complex	58.7	57.8	0.9	25.9	24.0	0.9

From the findings, the relative humidity at the selected locations changes in a range of 6 % to 11 % in 8 hours. It means that the level of moisture indoor is not stable and not well maintained, thus may give effects to the organic materials like wood, paper or textiles. In terms of temperature, the findings show that National Museum faced the highest change which is 2.2 oC, followed by 0.9 oC changes at Pasir Salak Historical Complex, and 0.8 oC at Beruas Museum.

The combination of high changes in temperature and humidity with airborne particulates may generate many harmful effects towards building materials or artefacts such as mould growth, corrosion of metal, brittleness of paper, textile become fragile, and shrinkage of wooden objects. The influence of moisture on the occurrence of defects cannot be underestimated. Over half of all defects will involve moisture in one form or another. Its main adverse consequence is dampness, which is still troublesome in many buildings today (Douglas and Ransom, 2007).

A rise in temperature leads to an increase in the rate of reactions and can accelerate many degradation processes. (An increase of 10 oC doubles the rate of many chemical reactions.) High temperature, in themselves also leads to high rate of evaporation and volatilization. Loss of volatiles from materials can cause shrinkage and brittleness. Evaporation of water can lead to early weakness, poor adhesion and cracking as stated by Douglas and Ransom (2007).

3.3. Effects of airborne particulates towards human health

Health means being in a state of complete physical, mental, and social well-being and not merely the absence of disease or infirmity (WHO, 2010). Thus, it can be explained that the impact of air pollution on human health is the direct effect from the particulates matter towards the well-being of human health. TSP and black smoke were used as indicators of airborne particles in the past but TSP has lost relevance because these can be filtered by nose and mouth. PM_{10} and $PM_{2.5}$ is preferred for more targeted response to the problems related with PM exposure as they are more dangerous to public health. Airborne particulates may become harmful to human health that can cause Lung disease, Asthma, Strokes,

respiratory tract disorders, numerous forms of cancer, eyes or skin irritations and allergic (Senthamizhvanan, 2010).

As stated by Gaynor Barade (2010), lack of proper ventilation causes the radon emission from the earth to be trapped indoors, within houses and offices. The use of air fresheners, pesticides and chemical sprays also put the people in the immediate environment at risk of developing respiratory tract disorders, poisoning and fatalities.Toxic asbestos fibers, dust and fumes cause Mesothelioma, a cancer that eats into the mesothelium, a delicate tissue that engulfs and protects important organs such as the heart and the lungs. While pets shed dander into the atmosphere, humans produce dust from dead skin flakes and the decomposition of hair.

Lookwood et. al., (2009) and Norsyamimi Hanapi (2011) have studied the effects of airborne particulates generated by coal power plant towards human health in United States (US) and Malaysia. As reported, Coal pollutants affect all major body organ systems and contribute to four of the five leading causes of mortality in the countries (heart disease, cancer, stroke, and chronic lower respiratory diseases). However, Manjung Coal-Fired Power Plant at Perak Darul Ridzuan, Malaysia has provided the safety preparation for lower emission of coal particulates from the combustion process (Alstom Power, 2009).

People that are most affected by the hazardous effects of airborne particulates are infant/babies, pregnant women, elderly people and those which have serious illness like diabetes, failure heart functions and lung disease. Hagan (1998) states that the broader the range of manifestations or symptoms, the less likely it is responsible for the health effects. Various symptoms grouped together as health effects can be overly unsophisticated and fraught with error besides may cause itchy eye and asthma symptoms.

3.4. Airborne particulates impact on cultural heritage

Air pollution has various effects on historical heritage materials such as the corrosion of metals, the deterioration of materials and paints, also the fading of dyes. Sulphur Oxide (SO) mostly affects material such as metals, cottons, finishes, coatings, building stone, paints, paper, and leather. Ozone (O_3) as well as Nitrogen oxide (NO_x) is able to attack and damage on materials like rubber, dyes, and paints. Besides, Carbon dioxide (CO_2) is also a kind of hazardous gas that can give harmful effects towards historical heritage materials especially building stone while particulates matter commonly attack on the materials such as stone, clay, metal, fibres and glass. This research figure out the damage and decays of artefacts at selected museum (Beruas Museum). The deterioration of materials caused by various possible factors such as, excessive moisture in air, high temperature, particulates (dust, pollen), exposure to the light, mould attack, insects attack, microorganisms (bacteria), chemical reaction of materials, mishandling and improper storage and display methods. Fig.5 shows the impact of airborne particulates and other agents of decay towards artefacts at Beruas Museum.

Fig. 5. (a) Bronze disease and metal corrosion; (b) White rots / mould growth

Literature reports many degradation cases of heritage objects' constituent materials such as paper, leather, textiles, pigments, and metal by the air pollutions (Puica and Ardelean, 2008). The effects of indoor air pollutions towards materials are different and variety due to the type of pollutants in the air. R Ahmad (2010) stated that the negative impact can occur when the pollutants react with the other environmental factors such as moisture, air, salt, particulate matter, ozone, light, physical wear, washing, sunlight, temperature, microorganism and etc.

4. Conclusion and recommendation

Based on the research findings, this study or knowledge seems to be new in Malaysia and it was getting more serious. Lack of the information from the government restricts accurate data to be achieved. Compared to the studies done by Singapore researchers, nowadays they are focusing deeper on fine particles effects and the contributors of the particles in that country, but Malaysia is still focusing on TSP which are not specific and wider. Lots of people have heard about these issues but they do not have details information about this topic and we need to do more research to spread the knowledge. From this research, it is found that all sampling location had exceeded the limit of Malaysia standard PM_{10} and TSP standard by DOE (2006). This means that indoor air quality of selected cultural heritage buildings were not safe to the occupants and visitors as it may bring negative impact towards them. In fact, it can affect their productivity, moral and satisfaction relation at work station.

Indoor air pollution is the best scope of research to be conducted as the particulates generated by industrial activities such as coal power plants stations, transportations and construction works have become a very dangerous threat to human health and cultural heritage objects. As the built environment being developed drastically nowadays, it is vital to balance it with museum occupant's or visitor's health and also to consider those pollutant effects towards historical heritage items and materials. Therefore, as the air is the most important elements in living, the level of particulates suspended in the air that exceeds the limit of standard total suspended particulates (TSP) in Malaysia, will give harmful effects towards human health and the nature of materials. This research is to be beneficial for museum occupants and visitors especially those which are exposed to the sources of particulates such as coal power plant station, construction works, and vehicles.

In terms of airborne particulate matter (PM), the emissions can be minimized by pollution prevention and emission control measures. Prevention which is frequently more cost-effective than control should be emphasized. Special attention should be given to pollution abatement measures in areas in where toxics associated with particulates emissions may pose a significant environmental risk. Measures such as improve process design, operation, maintenance, housekeeping, and other management practices can reduce emissions. As highlighted by Pupatunda (2010) in her article, nowadays there are many technologies available that can be used to control air pollution. For example, reduce the dependence on fossil fuels for energy requirements, and shift instead to using environmentally friendly renewable sources of energy. There are some opinions or suggestions to reduce the particulates emission inside building in order to decrease the bad impacts of airborne particulates towards human health and artefacts:-

- Adding a conventional mechanical ventilation and particle filtration system
- Reducing ventilation rates in which outdoor air enters the building
- Improving particles filtration
- Using display cases and framing methods for displaying artefacts
- Site management to achieve low outdoor particulates concentration
- Limiting sources of indoor pollutants ; cleaning and vacuuming
- Control the use of HVAC system

- Provide open space and organic plants as an alternative method

More studies need to be carried out to understand the dangerous effects of Airborne particulates towards human health, nature and materials. The Ministry of Health (MOH) or government of Malaysia through DOE need to increase the level of information on air pollution. Thus, should provide or manage the number of campaign, talk, seminar and workshop about the risky level of air pollution in Malaysia that can give answers to all problem issues that have been discussed in this paper. The in-depth study of the airborne particulates effect towards human health and materials in Malaysia, as well as the relationship between both subjects should also be studied further and investigated. Future research studies should look into physical characterizations and size distributions of airborne particulates generated by different sources of nature events and human activities in Malaysia.

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